GEOTEST ENGINEERING, INC.

Geotechnical Engineers & Materials Testing

5600 Bintliff Drive Houston, Texas 77036 Telephone: (713) 266-0588
Fax: (713) 266-2977

Job No. 1140196001
Trench Safety Report
October 22, 2013

Mr. H. Prasad Kolluru, P.E.
Amani Engineering, Inc.
8313 Southwest Freeway, Suite 350
Houston, Texas 77074

Reference: Trench Safety Design Considerations
Water Line Replacement in
Sharpstown II Area
WBS No. S-000035-0194-4
Houston, Texas

Dear Mr. Kolluru:

We are pleased to present our geotechnical information for trench safety for the referenced project.

For trench excavation, it is essential to maintain the stability of the sides and base and not to disturb the soil below the excavation grade. This is necessary to prevent any damage to adjacent facilities as a result of either vertical or lateral movements of the soil. In addition, a satisfactory excavation procedure must include an adequate construction dewatering system to lower and maintain the water level at least 3 feet below the lowest excavation grade or a minimum of 5 feet below prevailing level of backfill during backfilling. This will minimize the potential for softening or "boiling" of the base support soil.

Trench Excavation (Auger Pits)

Based on the information provided by Amani Engineering, Inc., it is understood that the water line replacement will be by trenchless method of construction. The following subsections provide information for the design and construction of the water lines and the excavations required for the proposed auger pit installation.

Geotechnical Parameters. Based on the soil conditions revealed by the borings GB-1 through GB-56, borings B-1 through B-3 and B-9 (from previous study), geotechnical parameters were developed for the design of auger pit construction as part of the water line replacement. The design parameters are provided in Table 1. For design, the groundwater level should be assumed to exist at the ground surface.

Excavation Stability (Auger Pits). The open excavation may be shored or laid back to a stable slope or supported by some other equivalent means used to provide safety for workers and adjacent structures, if any. The excavating operations should be in accordance with OSHA Standards, OSHA 2207, Subpart P, latest revision and the City of Houston Standard Specification.

- Excavation Shallower Than 5 Feet - Excavations that are less than 5 feet deep **(critical height)** should be effectively protected when an indication of dangerous ground movement is anticipated.

- Excavations Deeper Than 5 Feet - Excavations that are deeper than 5 feet should be sloped, shored, sheeted, braced or laid back to a stable slope or supported by some other equivalent means or protection such that workers are not exposed to moving ground or cave-ins. The slopes and shoring should be in accordance with the trench safety requirements as per OSHA Standards. The following items provide design criteria for excavation stability.

  (i) OSHA Soil Type. Based on the soil conditions revealed by borings drilled for this study and assumed groundwater level at surface, OSHA soil type "C" should be used for determination of allowable maximum slope and/or the design of shoring along the alignment for full proposed depth of open excavation. For shoring deeper than 20 feet (if needed), an engineering evaluation is required and deeper soil borings will be needed.

(ii) Excavation Support Earth Pressure. Based on the subsurface conditions indicated by our field investigation and laboratory testing results, excavation support earth pressure diagrams were developed and are presented on Figures 1.1 through 1.3. These pressure diagrams can be used for the design of temporary trench bracing. For a trench box, a lateral earth pressure resulting from an equivalent fluid with a unit weight of 93 pcf can be used. The effects of any surcharge loads at the ground surface should be added to the computed lateral earth pressures. A surcharge load, q, will typically result in a lateral load equal to 0.5 q. The above value of equivalent fluid pressure is based on assumption that the groundwater level is near the ground surface, since these conditions may exist after a heavy rain or flooding.

(iii) Bottom Stability. In braced cuts, if tight sheeting is terminated at the base of the cut, the bottom of the excavation can become unstable. The parameters that govern the stability of the excavation base are the soil shear strength and the differential hydrostatic head between the groundwater level within the retained soils and the groundwater level at the interior of the trench excavation. For cut in cohesive soils as predominantly encountered for the proposed excavation depths in most of the borings, the bottom stability can be evaluated as outlined on Figure 2. However, at locations near borings GB-14, GB-25, GB-26 and GB-38 where cohesionless soils (such as silty sand) were encountered between depths of 9.5 and 23 feet (at invert or within 3 feet of bottom of excavation), dewatering will be necessary to avoid bottom stability problems, if excavation are planned during or after a heavy rainfall season.

Groundwater Control. Excavations for the water line may encounter groundwater seepage to varying degrees depending upon the groundwater conditions at the time of construction and the location and depth of the trench.

In general for cohesive soils as predominantly encountered for most of the borings for the excavation depths, the groundwater if encountered may be managed by collection in excavation bottom sumps for pumped disposal. However, in borings GB-14, GB-25, GB-26 and GB-38 where cohesionless soils were encountered at invert or within 3 feet of bottom of the excavation; dewatering will be required, if the excavation is planned during or after a heavy rainfall event. Dewatering such as vacuum well points up to 15 feet or deep wells with submersible pumps for excavation greater than 15 feet may be required to lower the groundwater level to at least 5 feet below the bottom of the excavation (auger pits). It is recommended that the actual groundwater conditions should be verified by the contractor at the time of construction and that groundwater control should be performed in general accordance with the City of Houston Standard Specifications, Section 01578.

We appreciate this opportunity to be of service to you. If you have any questions regarding the report, or if we can be of further service to you, please call us.

Sincerely,
GEOTEST ENGINEERING, INC.
TBPE Registration No. F-410

K. Naresh

Naresh Kolli, P.E.
Assistant Project Manager

STATE OF TEXAS
10/22/13
NARESH KOLLI
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PROFESSIONAL ENGINEER

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Copies Submitted: (2)
Enclosures: Trench Support Earth Pressure – Figures 1.1 thru 1.3
Stability of Bottom for Braced Cut – Figure 2
Geotechnical Design Parameter Summary: Open-cut Excavation – Table 1
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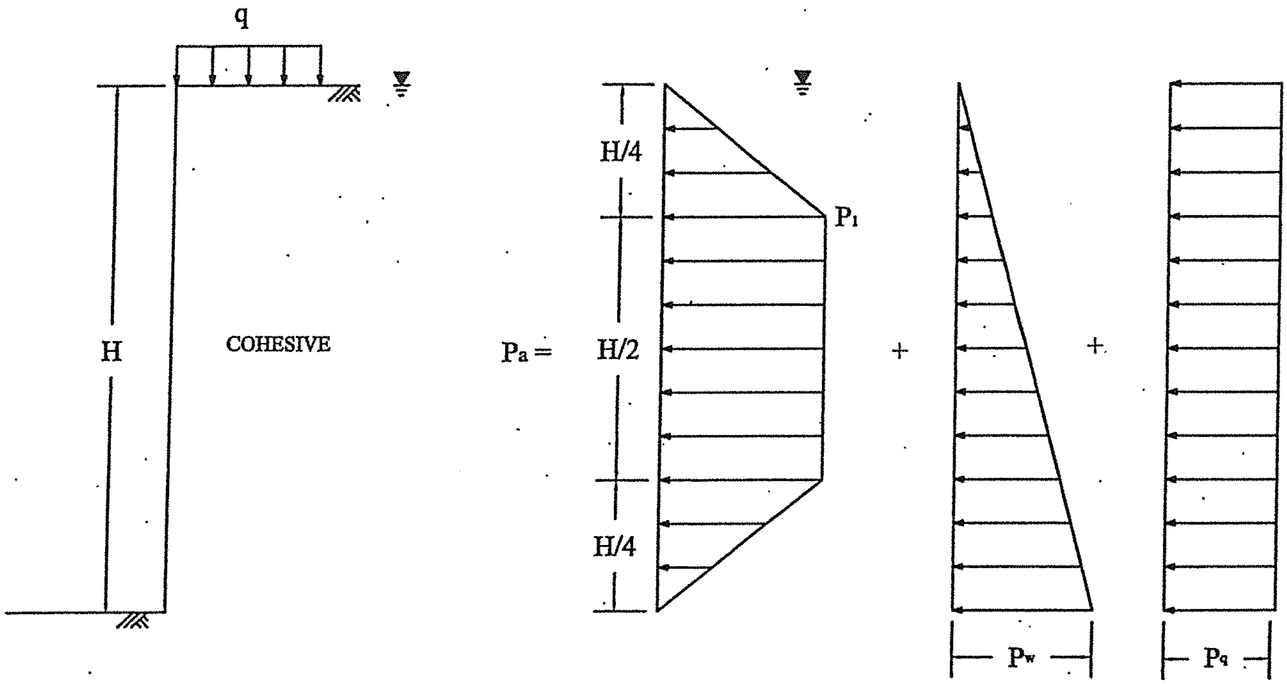


TYPICAL SOIL PARAMETERS

See Table 1 for typical values of soil parameters

BRACED WALL

For $\gamma H/c \leq 4$

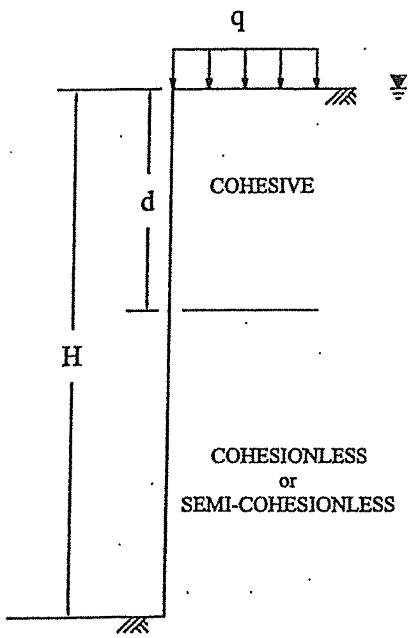
$P_1 = 0.3\ \gamma_c'\ H$
$P_w = \gamma_w\ H = 62.4\ H$
$P_q = 0.5\ q$

Where:

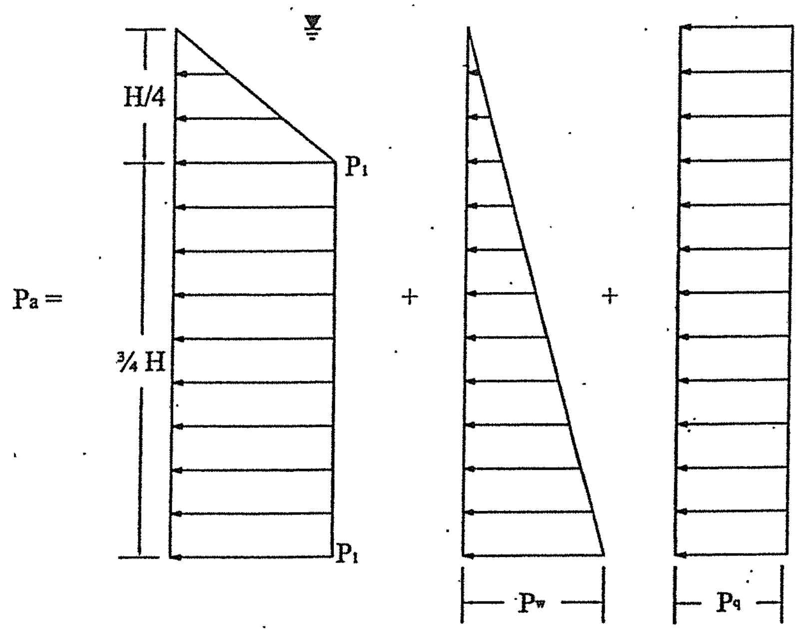
- γ_c' = Submerged unit weight of cohesive soil, pcf;
- γ_w = Unit weight of water, pcf;
- q = Surcharge load at surface, psf;
- P_a = Lateral pressure, psf;
- P_1 = Active earth pressure, psf;
- P_q = Horizontal pressure due to surcharge, psf;
- P_w = Hydrostatic pressure due to groundwater, psf;
- H = Depth of braced excavation, feet
- c = Shear strength of cohesion soil, psf;

TRENCH SUPPORT EARTH PRESSURE

SUBMERGED COHESIVE SOIL



TYPICAL SOIL PARAMETERS



BRACED WALL

See Table 1 for typical values of soil parameters.

$$\gamma'_{avg} = \frac{\gamma_c' \, d + \gamma_s' \, (H-d)}{H}$$

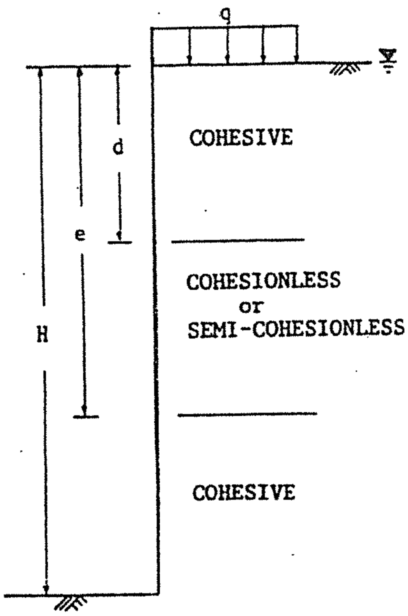
$P_1 = 0.3\ \gamma'_{avg}\ H$
$P_w = 62.4\ H$
$P_q = 0.5\ q$

Where:

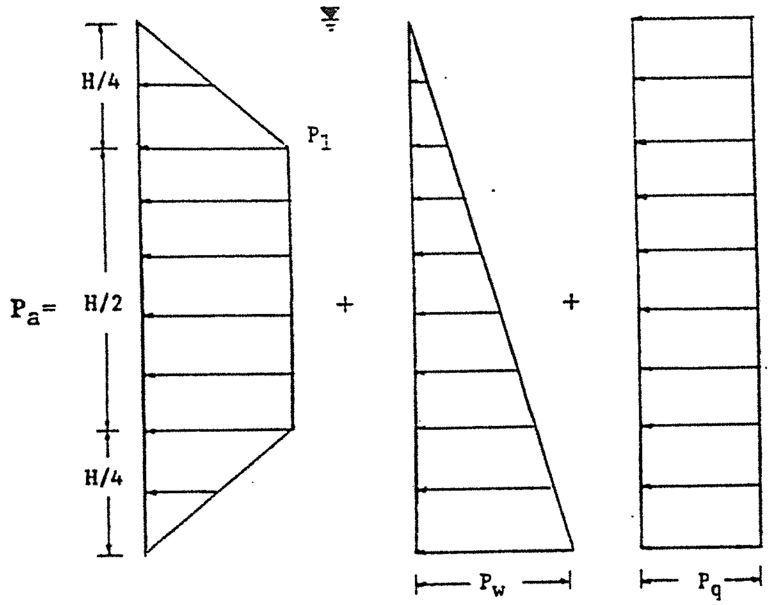
- γ_c' = Submerged unit weight of cohesive soil, pcf;
- γ_s' = Submerged unit weight of cohesionless soil, pcf;
- γ'_{avg} = Average submerged unit weight of soils, pcf;
- q = Surcharge load at surface, psf;
- P_a = Lateral pressure, psf;
- P_1 = Active earth pressure, psf;
- P_q = Horizontal pressure due to surcharge, psf;
- P_w = Hydrostatic pressure due to groundwater, psf;
- H = Depth of braced excavation, feet

TRENCH SUPPORT EARTH PRESSURE

SUBMERGED COHESIVE SOIL OVER
COHESIONLESS OR SEMI-COHESIONLESS SOIL



TYPICAL SOIL PARAMETERS



BRACED WALL

See Table 1 for typical
values of soil parameters

$P_1 = 0.3\ \gamma'_{avg}\ H$

$P_w = \gamma_w\ H = 62.4\ H$

$P_q = 0.5_q$

$$\gamma'_{avg} = \frac{\gamma_c'\ d + \gamma_s'\ (e-d) + \gamma_c'\ (H-e)}{H}$$

$\gamma_w = 62.4$ pcf

Where:

γ_c' = Submerged unit weight of cohesive soil, pcf ;
γ_s' = Submerged unit weight of cohesionless or semi-cohesionless soil, pcf ;
γ_w = Unit weight of water, pcf;
γ'_{avg} = Average submerged unit weight of soil, pcf ;
q = Surcharge load at surface, psf;
P_a = Lateral pressure, psf;
P_1 = Active earth pressure, psf;
P_q = Horizontal pressure due to surcharge, psf;
P_w = Hydrostatic pressure due to groundwater, psf;
H = Depth of braced excavation, feet

TRENCH SUPPORT EARTH PRESSURE

SUBMERGED COHESIVE SOIL
INTERBEDDED WITH COHESIONLESS OR
SEMI-COHESIONLESS SOIL

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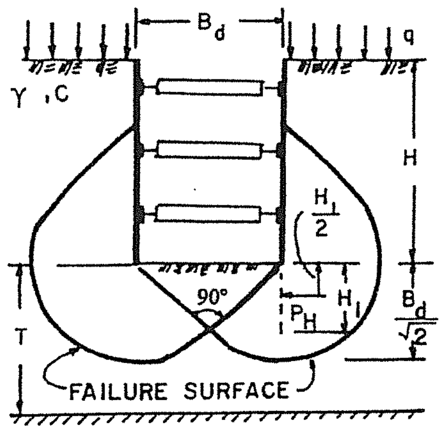
CUT IN COHESIVE SOIL,
DEPTH OF COHESIVE SOIL UNLIMITED ($T > 0.7\ B_d$)
L = LENGTH OF CUT



If sheeting terminates at base of cut:

$$\text{Safety factor, } F_S = \frac{N_C C}{\gamma H + q}$$

N_C	=	Bearing capacity factor, which depends on dimensions of the excavation : B_d, L and H (use N_c from graph below)
C	=	Undrained shear strength of clay in failure zone beneath and surrounding base of cut
γ	=	Wet unit weight of soil (see Table 1)
q	=	Surface surcharge (assume q = 500 psf)

If safety factor is less than 1.5, sheeting or soldier piles must be carried below the base of cut to insure stability - (see note)

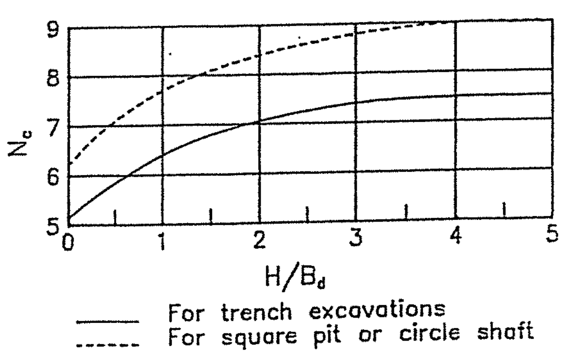
$$H_1 = \text{Buried length} = \frac{B_d}{2} \geq 5 \text{ feet}$$

Note : If soldier piles are used, the center to center spacing should not exceed 3 times the width or diameter of soldier pile .

Force on buried length, P_H:

If $H_1 > \frac{2}{3}\frac{B_d}{\sqrt{2}}$, $P_H = 0.7\,(\gamma HB_d - 1.4CH - \pi CB_d)$ in lbs/ linear foot

If $H_1 < \frac{2}{3}\frac{B_d}{\sqrt{2}}$, $P_H = 1.5H_1\,(\gamma H - \frac{1.4CH}{B_d} - \pi C)$ in lbs/ linear foot



STABILITY OF BOTTOM
FOR
BRACED CUT

Geotest Engineering, Inc.

FIGURE 2

TABLE 1

GEOTECHNICAL DESIGN PARAMETER SUMMARY
OPEN-CUT EXCAVATION (AUGER PITS)

Alignments	Boring Nos.	Stratigraphic Unit	Range of Depths, ft	Wet Unit Weight, γ, pcf	Submerged Unit Weight, γ', pcf	Undrained Cohesion, psf	Internal Friction Angle, φ, degree
8" Waterline along Brae Acres	GB-1 thru GB-7	Cohesive	0-8 8-12 12-17	125 128 130	63 64 65	1,000 800 2,000	-- -- --
	GB-8	Cohesive Cohesionless	0-12 12-23	125 112	63 56	1,200 --	-- 30
8" Waterline along Troulon	GB-9, GB-10, GB-31, GB-32, GB-45 and GB-46	Cohesive	0-12	125	63	1,000	--
8" Waterline along Tanager	GB-2, GB-33, GB-34, and B-1 through B-3 (Previous Study)	Cohesive	0-4 4-6 6-10 10-15	130 132 134 130	65 66 67 60	1,200 2,600 2,400 1,600	-- -- -- --
	GB-11	Cohesive Cohesionless	0-8 8-11 11-17	130 130 102	65 65 51	1,000 800 --	-- -- 30
8" Waterline along Carew	GB-12 and GB-14	Cohesive Cohesionless Cohesive (GB-14 only)	0-10 10-16 16-17	125 106 120	63 53 60	800 -- 1,000	-- 30 --
	GB-13 and GB-15	Cohesive	0-8 8-12 12-15	125 130 120	63 65 60	1500 500 900	-- -- --
8" Waterline along Grape	GB-17, GB-18, GB-27 and GB-37	Cohesive	0-10 10-14	125 130	63 65	1,000 1,000	-- --
8" Waterline along Jackwood	GB-5 and GB-19	Cohesive	0-4 4-16	125 125	63 63	1,500 2,000	-- --
8" Waterline along Jason	GB-20 and GB-29	Cohesive	0-4 4-18	125 130	63 65	500 1,500	-- --
8" Waterline along Imogene	GB-6, GB-22 and GB-23	Cohesive	0-10 10-14 14-18	126 130 125	63 65 63	1,500 800 1,000	-- -- --
8" Waterline along Braes River	GB-10, GB-13, GB-16, GB-18, GB-21	Cohesive	0-12 12-14	125 130	63 65	800 1000	-- --

TABLE 1 (cont'd)

GEOTECHNICAL DESIGN PARAMETER SUMMARY
OPEN-CUT EXCAVATION (AUGER PITS)

Alignments	Boring Nos.	Stratigraphic Unit	Range of Depths, ft	Wet Unit Weight, γ, Pcf	Submerged Unit Weight, γ', pcf	Undrained Cohesion, psf	Internal Friction Angle, φ, degree
12" Waterline along Braeburn Valley	GB-24, GB-27 through GB-30	Cohesive	0-2 2-8 8-15 15-23	120 125 130 125	60 63 65 63	1,200 1,500 1,200 2,000	-- -- -- --
	GB-25 and GB-26	Cohesive Cohesionless Cohesive	0-10 10-12 12-22 22-24	130 125 102 120	65 63 51 60	1,500 600 -- 2,200	-- -- 30 --
8" Waterline along Darnell	GB-35 and GB-36	Cohesive	0-6 6-10 10-12	130 130 125	65 65 63	1,500 2,500 2,000	-- -- --
8" Waterline along Reims	GB-37	Cohesive	0-6 6-12	128 125	64 63	3,000 1,000	-- --
8" Waterline along Jackwood	GB-38	Cohesive Cohesionless	0-10 10-17	130 100	65 50	3,000 --	-- 30
8" Waterline along Bonhomme	GB-39 through GB-44	Cohesive	0-6 6-12 12-18 18-24	125 130 125 125	63 65 63 63	1,600 1,000 2,000 2,200	-- -- -- --
8" Waterline along Lugary	GB-47 and B-2 (previous study)	Cohesive	0-10 10-12 12-15	125 125 125	63 63 63	1,000 2,000 2,200	-- -- --
8" to 12" Waterline along Backlines (Easements A, B, C & D)	GB-48 through GB-52	Cohesive	0-6 6-12	125 130	63 65	500 1,000	-- --
8" Waterline along Kingsgate Circle	GB-53	Cohesive	0-4 4-12	120 130	60 65	500 1,800	-- --
	GB-54	Cohesive Cohesionless	0-6 6-12 12-14 14-24	125 115 120 106	63 58 60 53	800 2,000 800 --	-- -- -- 30
8" Waterline along Fonvilla	GB-55 and GB-56	Cohesive	0-6 6-12	126 125	63 63	1,600 1,500	-- --

Note: 1) Cohesive soils include Sandy Lean Clay, Lean Clay w/sand, Lean Clay, Fat Clay w/sand, Sandy Fat Clay and Fat Clay.
2) Cohesionless soils include Silty Sand and Fine Sand with silt.